Validation of the EOS MLS ClO Measurements

Aura Validation Meeting: 21 September 2005

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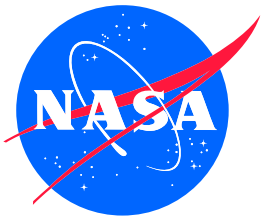
Odin/SMR Team

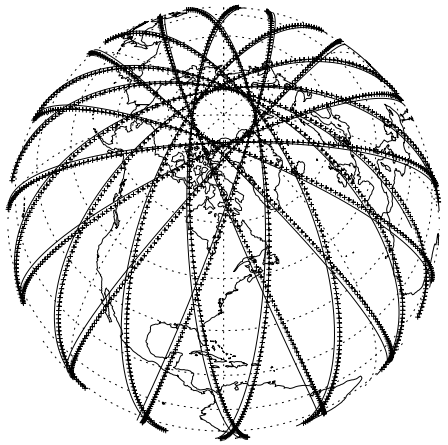


JPL

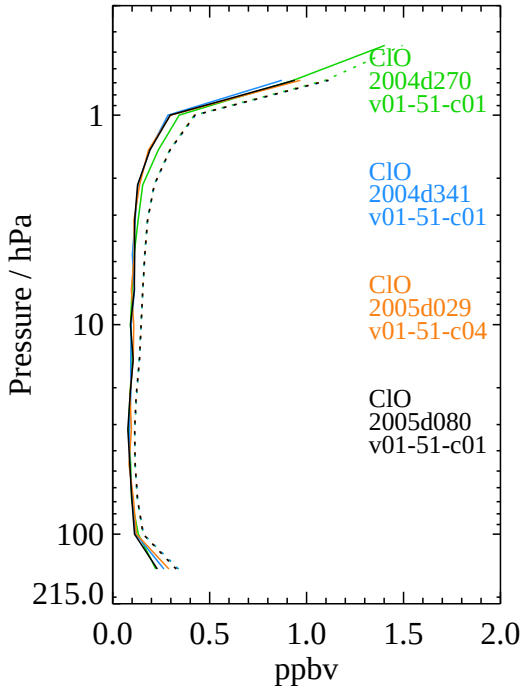
Overview of the EOS MLS ClO product

- The standard product for version 1.5 ClO is taken from the 640 GHz retrieval.
- V1.5 ClO data are scientifically useful over the range 100 to 1 hPa.
- MLS data are reported at six pressure levels per decade change in pressure (~2.5 km).
- The true vertical resolution is ~3 km over the range 100 to 10 hPa, degrading to ~5 km near the top of the profile.
- Adjacent profiles are separated by 1.5° great circle angle along the orbit track, corresponding to 165 km (24.7 s).
- Horizontal resolution is ~300–400 km along-track and ~3 km cross-track for the ClO measurements.
- Observed scatter in the data, evaluated in a 20°-wide latitude band centered around the equator where atmospheric variability is expected to be small in the lower stratosphere, indicates a measurement precision of 0.1–0.2 ppbv throughout the profile.
- The estimated single-profile precision reported by the Level 2 software agrees well with the observed scatter over most of the profile.
- It is recommended that ClO profiles for which `QUALITY` < 2.7 be discarded to eliminate obvious outliers.
- Clouds in the upper troposphere have no influence on the lower stratospheric ClO observations.

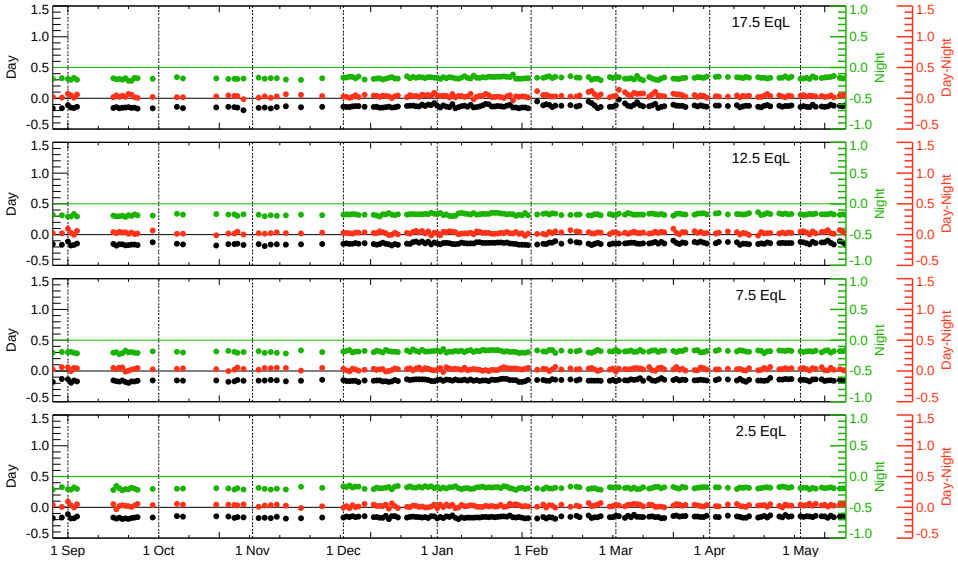
EOS MLS data coverage in a 24-hr period

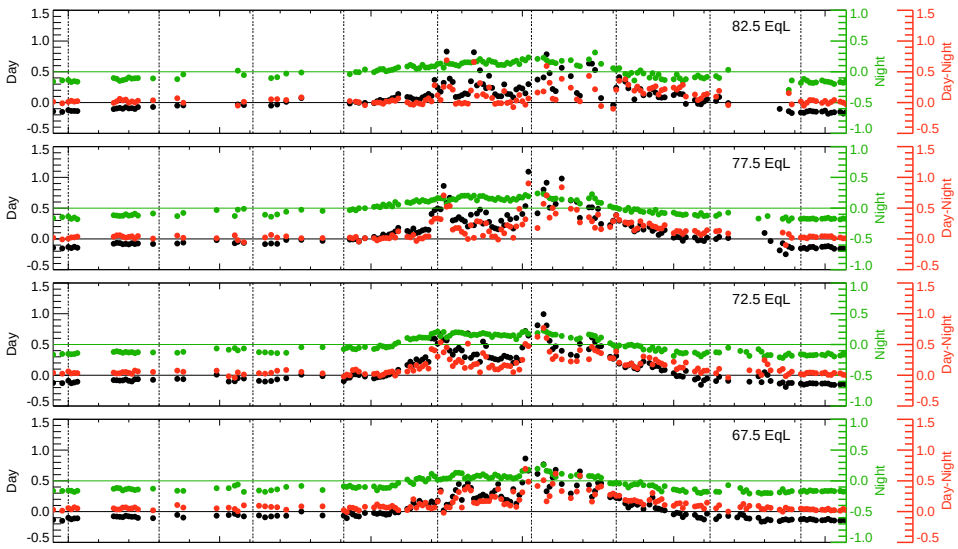


Est Prec vs Obs Scatter



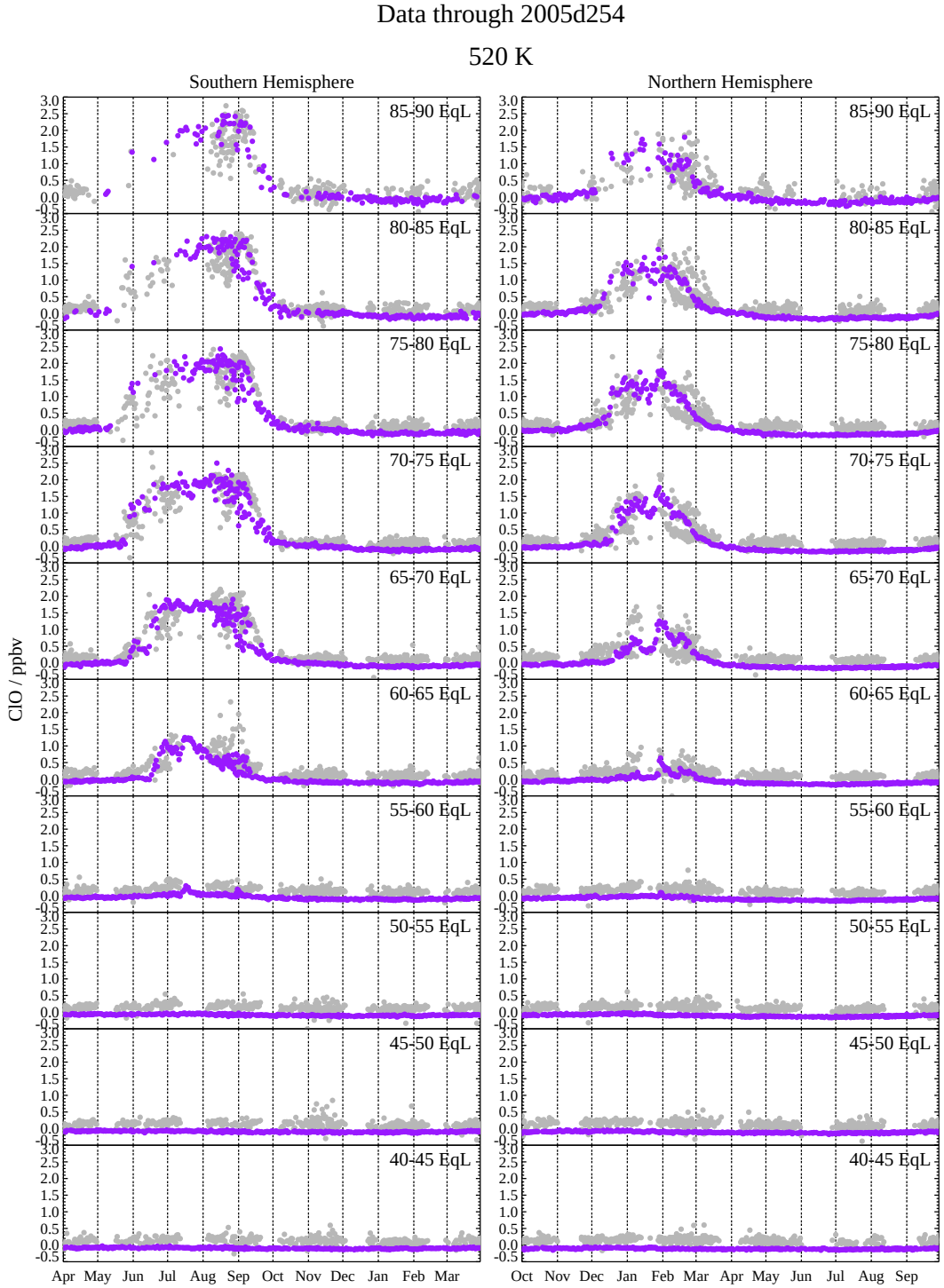
Known artifacts in the ClO retrievals





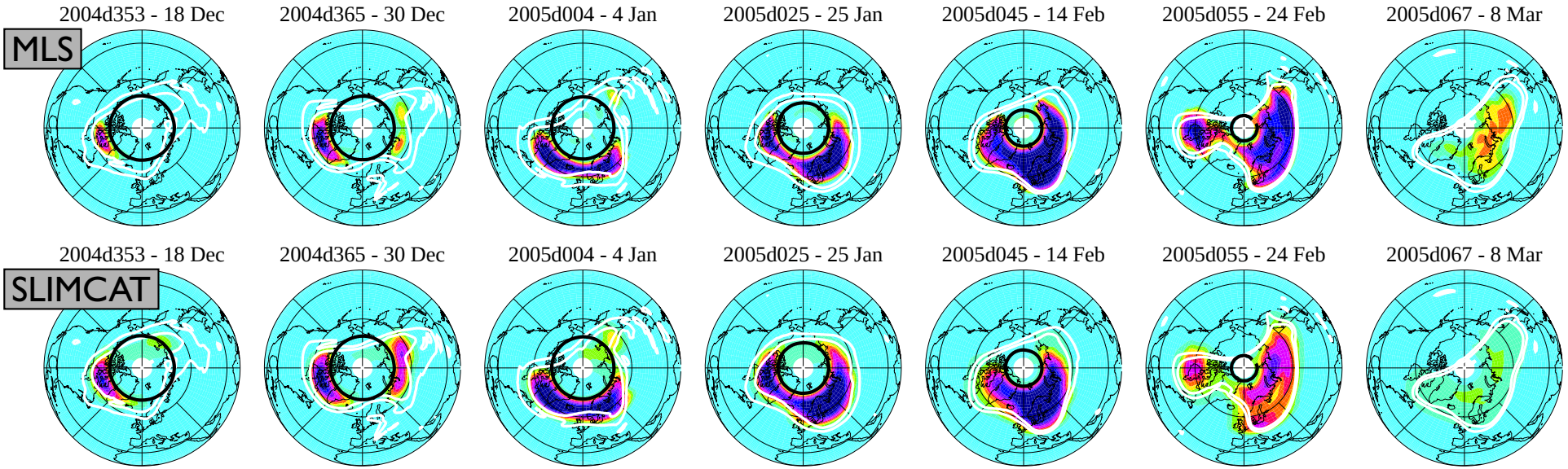
- MLS ClO **Day**, **Night**, and **Day-Night** values have been examined over the interval from 27 August 2004 to 16 May 2005 in 5° equivalent latitude bins on the 660, 580, 520, 460, and 410 K potential temperature surfaces (corresponding to pressures of 22, 32, 46, 68, and 100 hPa, respectively).
- No systematic biases in the ClO values are found at the top two levels.
- At 520 K and below, a pervasive negative bias of 0.2–0.3 ppbv in both **Day** and **Night** ClO mixing ratios is effectively eliminated by taking **Day-Night** differences.
- At polar latitudes, **Night** mixing ratios temporarily exhibit nonnegligible positive values during the winter; thus taking **Day-Night** differences reduces estimates of chlorine activation.
- This change in behavior in the winter high latitudes is largely absent in the 190-GHz ClO retrievals, suggesting that for the most part it does not arise from physical processes.
- Conclusion: A systematic negative bias as large as ~0.3 ppbv is present in the MLS ClO standard product at the lowest retrieval levels. Day-Night differences should be taken in studies for which knowledge of the ClO mixing ratio to better than ~0.3 ppbv is needed.

Comparison with UARS MLS ClO measurements

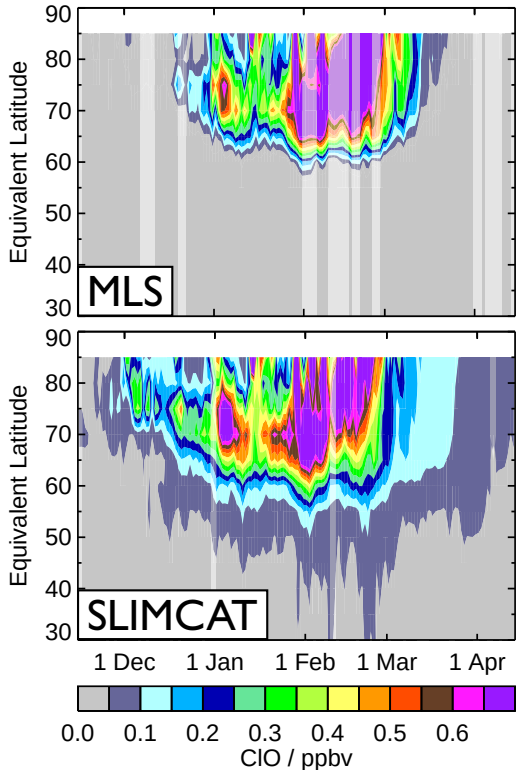


- This plot shows time series of MLS ClO at 520 K (~46 hPa, 19 km) for both the Southern (left) and Northern (right) Hemispheres.
- Grey dots show daily means in 5° equivalent latitude bands from 40 to 90° of data from the MLS instrument on UARS for 9 years (1991–2000).
- Purple dots show daily averages of EOS MLS ClO data from mid-August 2004 to mid-September 2005.
- Only daytime data (solar zenith angle $< 92°$ and local solar time between 10:00 and 15:00) were included in the averages.
- The evolution of ClO over an annual cycle, and the latitudinal distribution of enhanced wintertime ClO, matches that observed by UARS MLS extremely well.
- The low bias in the EOS MLS ClO data at this level shows up clearly in these comparisons.

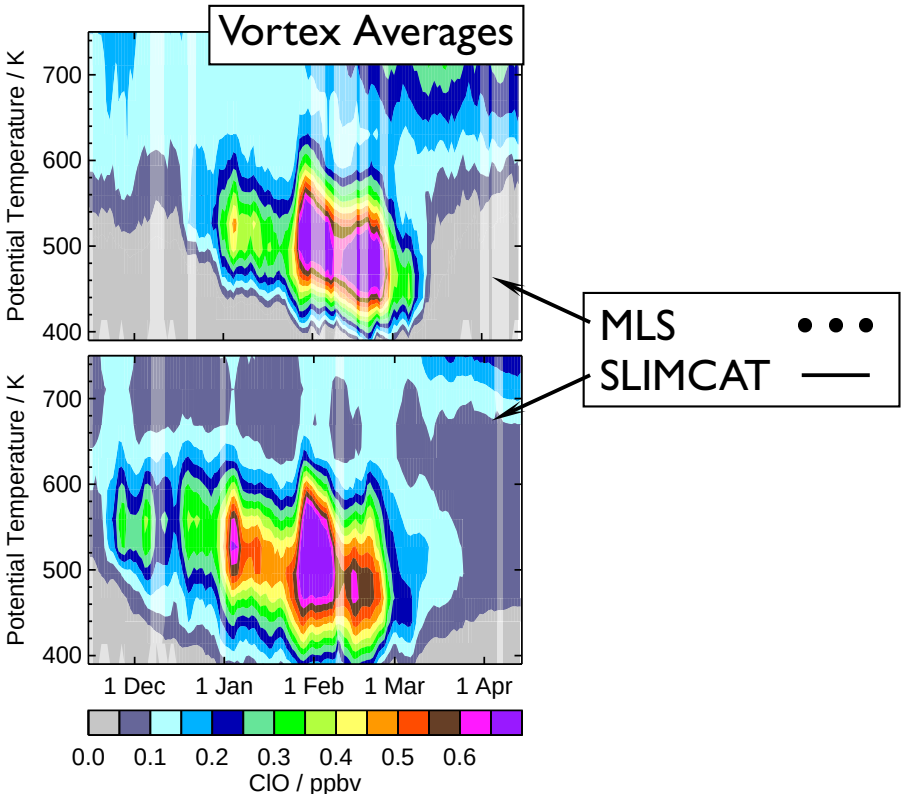
Comparison with SLIMCAT 3D chemical transport model results



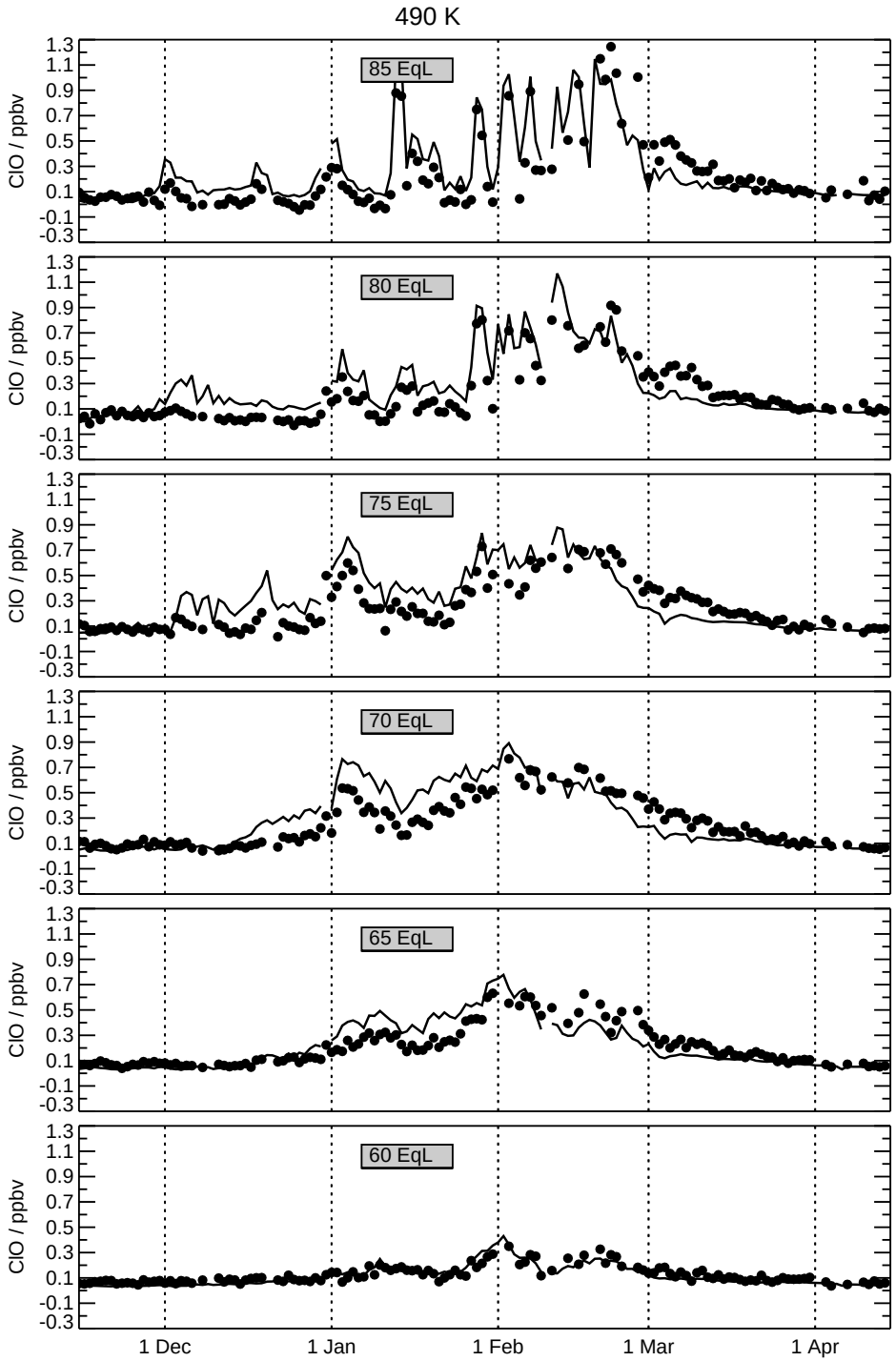
- MLS ClO data from the 2004–2005 Arctic winter are compared to results from near real time runs of the SLIMCAT CTM, sampled at the same location and local time as the EOS MLS measurements.
- Daily snapshots at 490 K show very similar morphology and timing of ClO enhancement in both data and model, although significant chlorine activation starts and ends slightly earlier in the model.
- This is seen more clearly in time series of daytime ClO as a function of equivalent latitude (490 K).
- Although the duration of mildly elevated ClO abundances is greater in the model, maximum mixing ratios near the profile peak persist longer into March in the MLS data.
- Otherwise the evolution of enhanced ClO is very similar throughout the vortex region.



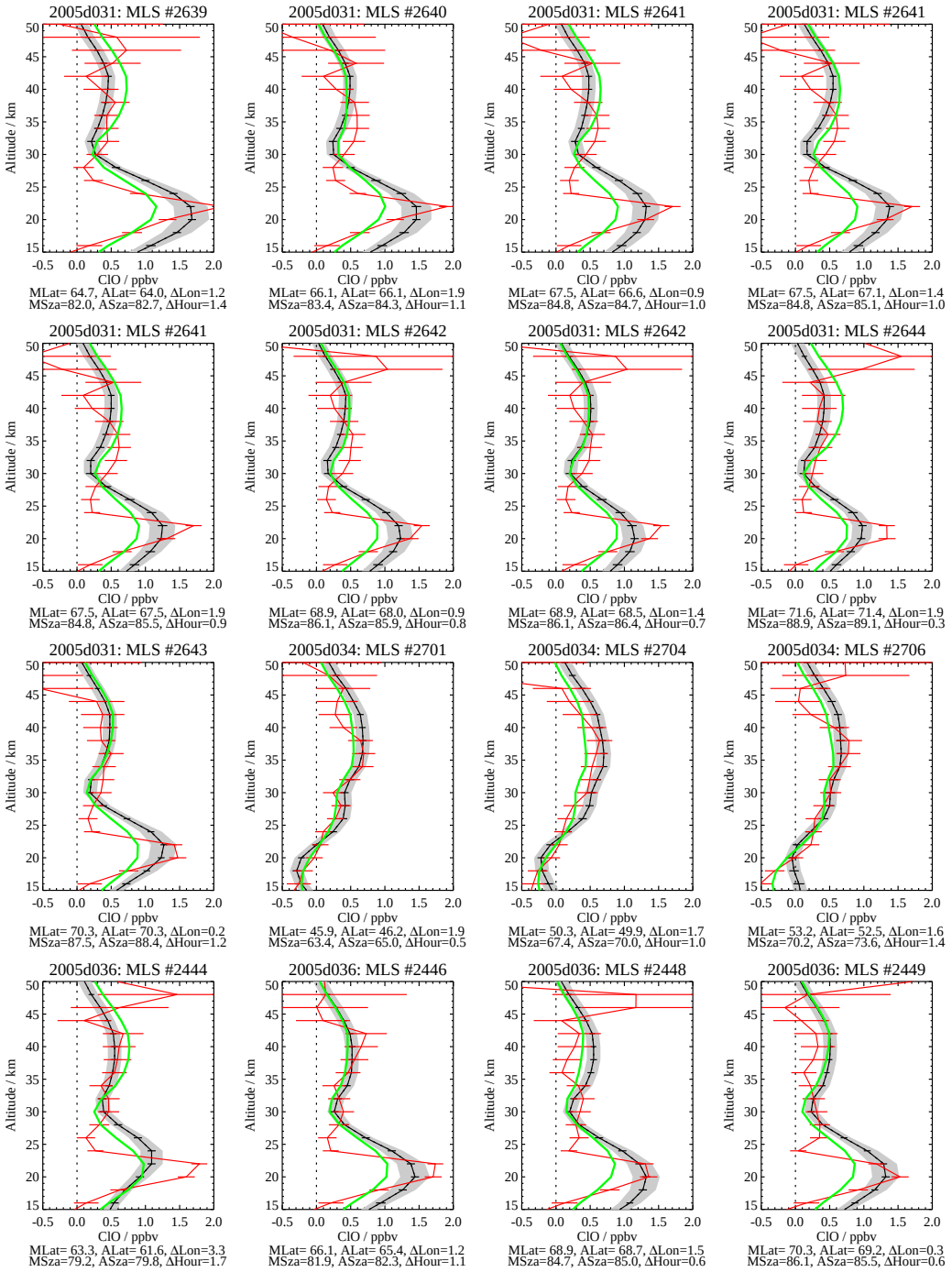
Comparison with SLIMCAT 3D chemical transport model results



- The relationship between equivalent latitude and solar zenith angle leads to large variations in ClO in the vortex core that are matched well by SLIMCAT.
- Similar plots based on preliminary data from the 2004 Antarctic winter showed qualitatively good agreement with theory [Santee et al., GRL 32, 2005]; agreement in v1.5 is improved.
- Chlorine activation does not extend as low in altitude in the MLS data because of the negative bias in ClO at the lowest retrieval levels.



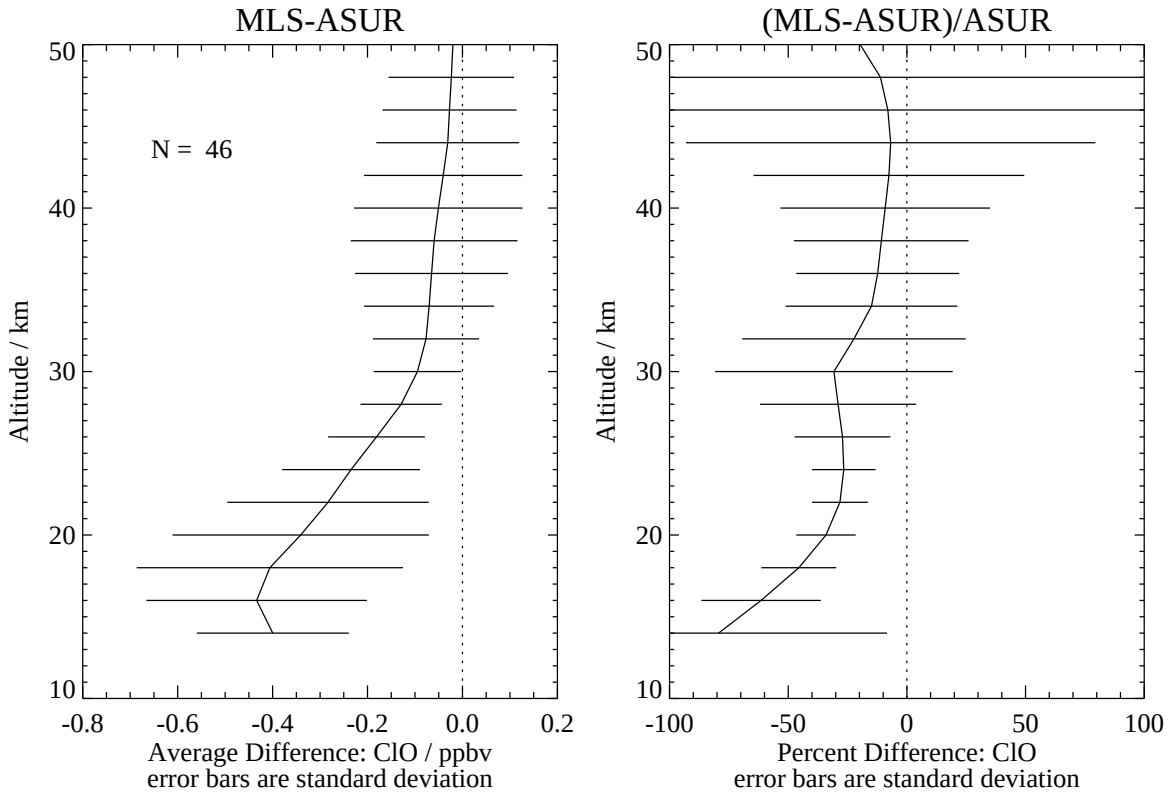
Comparisons with ASUR: representative individual profiles



ASUR with estimated precision (error bars) and accuracy (grey shading)
MLS with estimated precision
MLS multiplied by ASUR averaging kernels

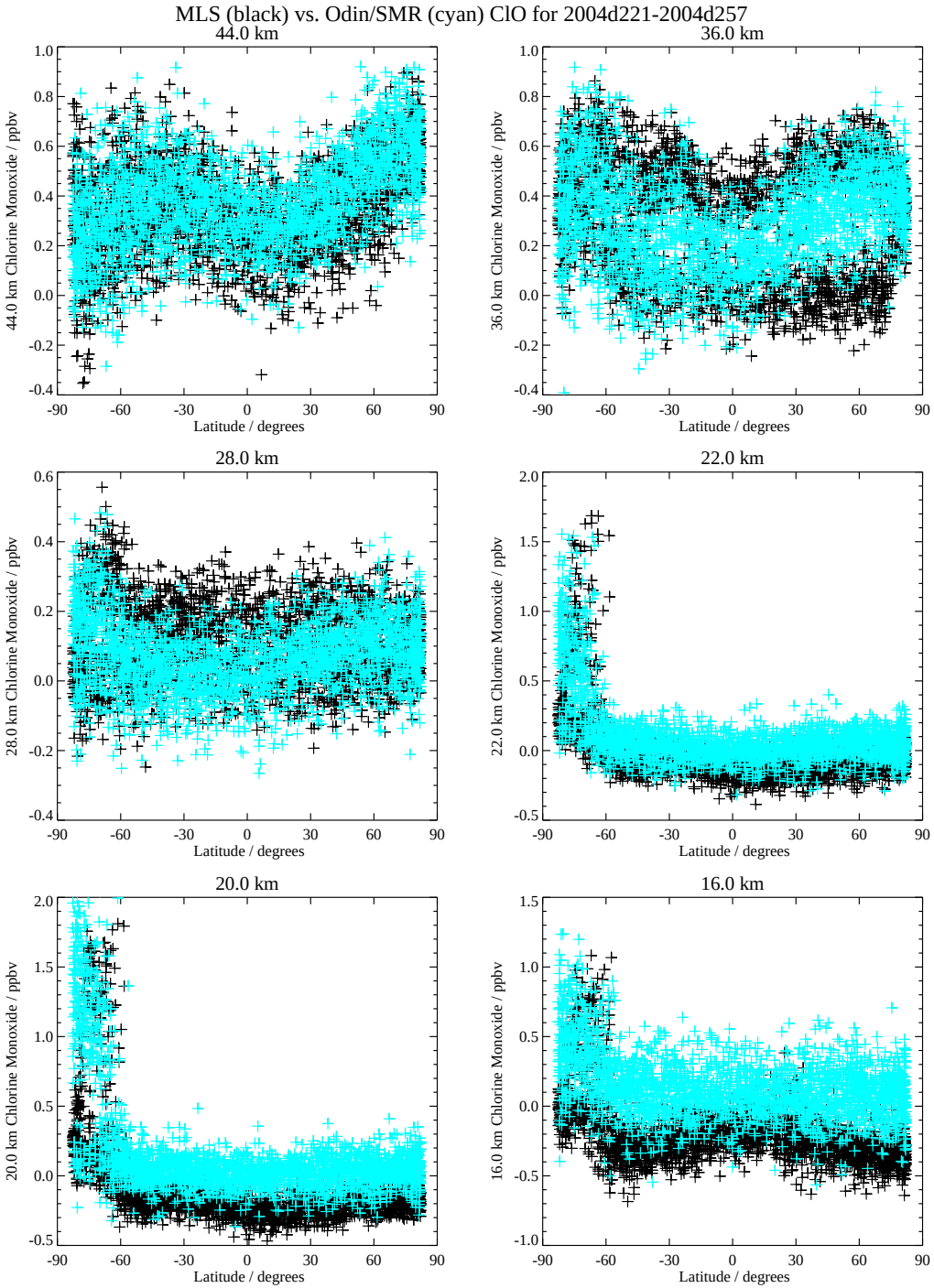
- The Airborne Submillimeter Radiometer (ASUR) flown on the DC-8 during PAVE (January/February 2005) measures ClO at 650 GHz from 14 to 50 km with 5–10 km vertical resolution and ~15% accuracy.
- Several of the PAVE flights underflew the MLS track.
- Coincidence criteria: ±2° latitude, ±4° longitude, ±2 hours.
- MLS, with better vertical resolution, observes a more sharply defined peak in ClO.
- Applying the ASUR averaging kernels to the MLS data generally improves the comparisons.
- Agreement is typically good near the high-altitude peak, and for those profiles where ClO is not enhanced, but the smoothed MLS profiles have smaller maximum abundances in the lower stratosphere.

Comparisons with ASUR: summary



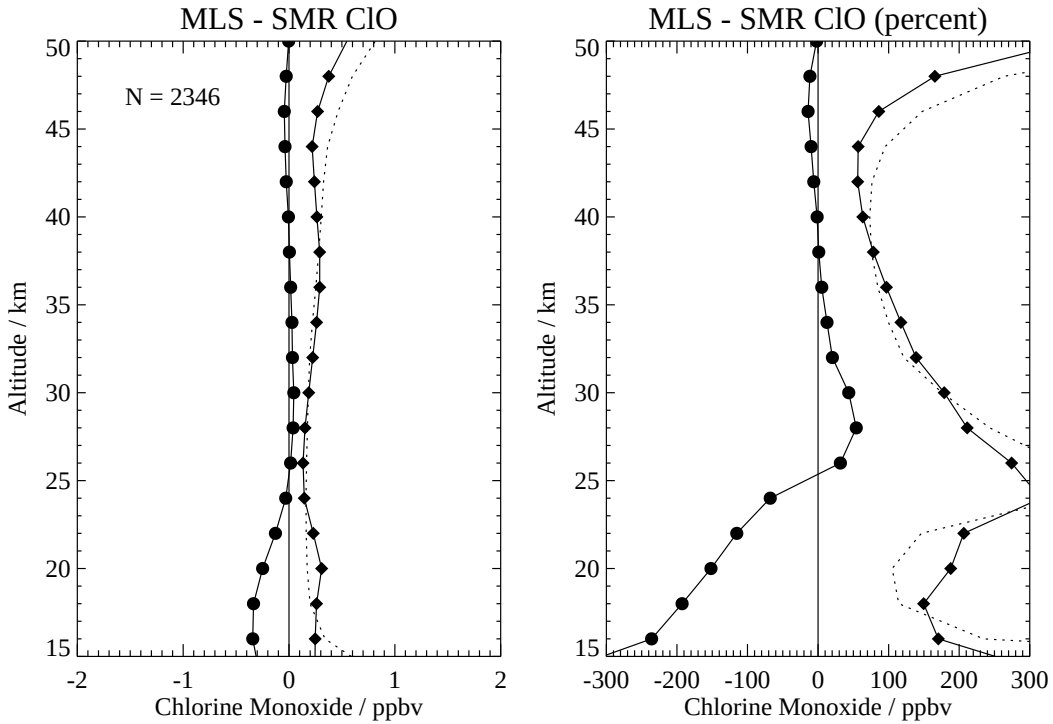
- Average differences between the MLS profiles multiplied by the ASUR averaging kernels and the ASUR profiles are quite small ($<$0.1 ppbv, 10–30%) above 30 km.
- However, average differences increase below 30 km to more than 0.4 ppbv at the lowest levels, where MLS ClO is known to have a negative bias.

Comparisons with Odin/SMR: scatter plots



- The submillimeter radiometer (SMR) was launched on Odin in February 2001.
- SMR measures ClO at 502 GHz from 15 to 55 km with 2–2.5 km vertical resolution.
- Here we show "Chalmers-v2.0" data; "Chalmers-v1.2" data had ~0.15–0.25 ppbv single-scan precision and an estimated systematic error of $<$0.02 ppbv above 25 km, increasing to 0.1 ppbv at ~16 km [Urban et al., JGR 110, 2005].
- **MLS** and **SMR** data are scattered vs. latitude for all coincident profiles over the interval 8 August to 13 September 2004.
- Coincidence criteria: $\pm 1^\circ$ latitude, $\pm 8^\circ$ longitude, ± 12 hours.
- Agreement is generally good, although the persistent negative bias in the MLS ClO data outside of the winter polar regions is evident at the lowest levels.
- Similar levels of winter polar enhancement in lower stratospheric ClO are measured by both MLS and SMR.
- In addition, very good agreement is found for the second peak in ClO around 40 km.

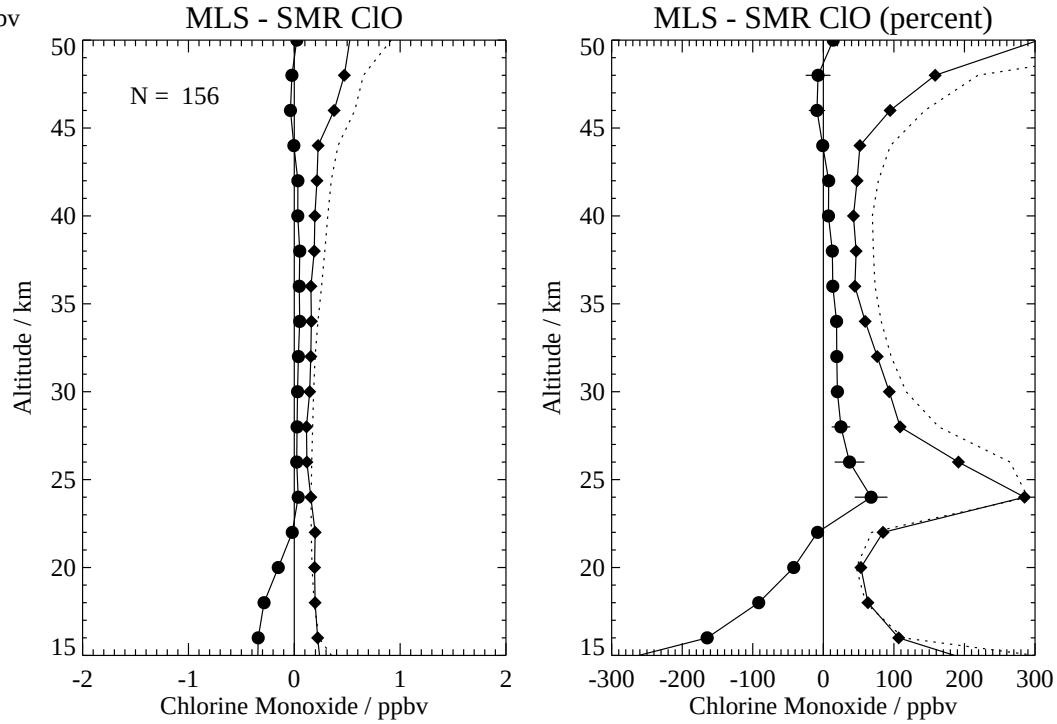
Comparisons with Odin/SMR: summary



Circles = mean difference, Diamonds = rms difference, Dotted = expected rms

- Average differences between MLS and SMR ClO are quite small ($<$0.1 ppbv) from 22 to 50 km, though percent differences are as large as 50%.
- At the lowest levels, MLS ClO is consistently lower than SMR ClO by 0.3 ppbv, reflecting the known negative bias in MLS ClO.
- Note that no solar zenith angle criteria were applied in selecting these matches.

- Imposing an additional $\pm 2°$ SZA criterion greatly reduces the number of matches but provides only moderate improvement in the comparisons.
- Most coincidences at high southern latitudes, where ClO is enhanced at this time, occurred at or near twilight, with MLS measuring in the evening but SMR measuring in the morning.
- These issues may complicate further detailed MLS/SMR comparisons.



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Summary and future work

- The standard product for v1.5 ClO is taken from the 640 GHz retrieval.

  Useful range: 100–1 hPa

  Vertical resolution: 3–5 km

  Horizontal resolution: ~300–400 km along-track, ~3 km cross-track; adjacent profiles separated by 1.5° (165 km)

  Precision: 0.1–0.2 ppbv throughout the vertical range

  Artifacts: A persistent negative bias of as much as 0.3 ppbv is seen at all latitudes and seasons outside of the winter polar regions at the lowest retrieval levels (at and below 46 hPa); taking Day-Night differences effectively eliminates this negative bias.

  Consistency checks: The seasonal evolution of polar ClO enhancement agrees very well with that measured by UARS MLS and predicted by the SLIMCAT CTM.

  Accuracy: MLS ClO agrees with ASUR and Odin/SMR ClO measurements at the 10–30% level, except at the lowest retrieval levels where a significant negative bias is present.

- Plans for further correlative studies include comparisons with MIPAS and ACE ClO measurements.
- Priorities for Version 2 MLS ClO data:
  - Reduce the persistent negative bias in the ClO mixing ratios at the lowest retrieval levels.
  - Attempt to improve the retrievals at 147 hPa.